Section 6

Developments in global forecast models, case studies, predictability investigations, global ensemble, monthly and seasonal forecasting

Relative influence of the tropical troposphere and extratropical stratosphere on Northern Hemisphere winter climate variability

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Given the low skill of operational dynamical seasonal forecasts in the Northern Hemisphere, it might be useful to come back to more idealized numerical studies in order to better understand the mechanisms and sources of climate predictability. Here a grid-point nudging technique is used to compare the relative influence of the tropical troposphere and extratropical stratosphere on the wintertime variability simulated by the Arpège-Climat atmospheric GCM in the northern extratropics. The control experiment consists of a 5-member ensemble of 1970-2000 global atmospheric simulations driven by observed sea surface temperature (SST) and radiative forcings (i.e. greenhouse gases and aerosols). Each member only differs by the atmospheric initial conditions on 1st January 1970. This AMIP-type ensemble is considered as a benchmark for evaluating potential (i.e. with prefect SST) seasonal predictability. Two additional 5-member ensembles have been performed using an additional nudging of winds and temperature towards the ERA40 reanalyses either between 25°S and 25°N (below 100 hPa) or north of 25°N (above 100hPa). The objective is to quantify the contribution of the tropical or stratospheric circulation to the simulated interannual variability. All simulations are performed with a medium-resolution and low-top configuration (linear T63 truncation, reduced 128 by 64 Gaussian grid, 31 hybrid σ-pressure vertical levels) of version 4 of the Arpège-Climat model (Guérémy et al. 2005). While the vertical resolution is too coarse to resolve the stratosphere (only 5 vertical levels above 100 hPa), it is sufficient to simulate a realistic polar vortex with the nudging strategy. In both sensitivity experiments, the vertical and latitudinal profiles of the nudging strength are chosen in order to ensure a smooth transition between the nudged and free atmosphere. The maximum nudging strength is fixed at a 5-hour e-folding time for wind components against 12 hours for temperature. The reference fields are the 6-hourly ERA40 data which are interpolated linearly at the model time step. More details about the nudging technique can be found in Douville (2009) and Douville et al. (2010).

Fig. 1 shows the simulation of two climate indices that summarize a significant fraction of the Northern Hemisphere wintertime variability: the Artic Oscillation (AO) index based on the first EOF of mean sea level pressure poleward of 20°N, and the North Atlantic Oscillation (NAO) index based on the first EOF of 500 hPa geopotential height over North Atlantic and Europe. All anomalies are relative to the 1971-2000 climatology and are based on raw DJF seasonal means without prior filtering. Not surprisingly, the control experiment shows a substantial spread and a limited skill at simulating the AO/NAO variability. In the nudging experiments, the spread is strongly reduced thereby suggesting a strong forcing of wintertime variability. Nevertheless, the skill improvement is much stronger when the nudging is applied in the northern stratosphere. In contrast and despite the reduction of spread, the AO variability is not improved in the tropical nudging experiment. This result suggests a possible deficiency of the Arpège-Climat GCM in the simulation of tropical-extratropical teleconnections. While our experiments confirm the strong influence of the stratospheric polar vortex on northern mid-latitude and particularly European wintertime variability (e.g. Scaife and Knight 2008, Douville 2009), tropical and stratospheric forcings are not necessarily independent and are therefore not additive. In a recent case study based on a similar experiment design, Jung et al. (2009) suggested for instance that the weak stratospheric polar vortex observed in winter 2005/06 could be explained by tropical circulation anomalies. In any case, Europe appears as a “hot spot” where seasonal forecasting could strongly benefit from an improved simulation of both stratospheric and tropical circulation. Further sensitivity experiments with a well resolved stratosphere and an improved atmospheric physics are therefore probably needed for a deeper understanding and a more precise evaluation of the upper limit of seasonal predictability in the Northern Hemisphere.

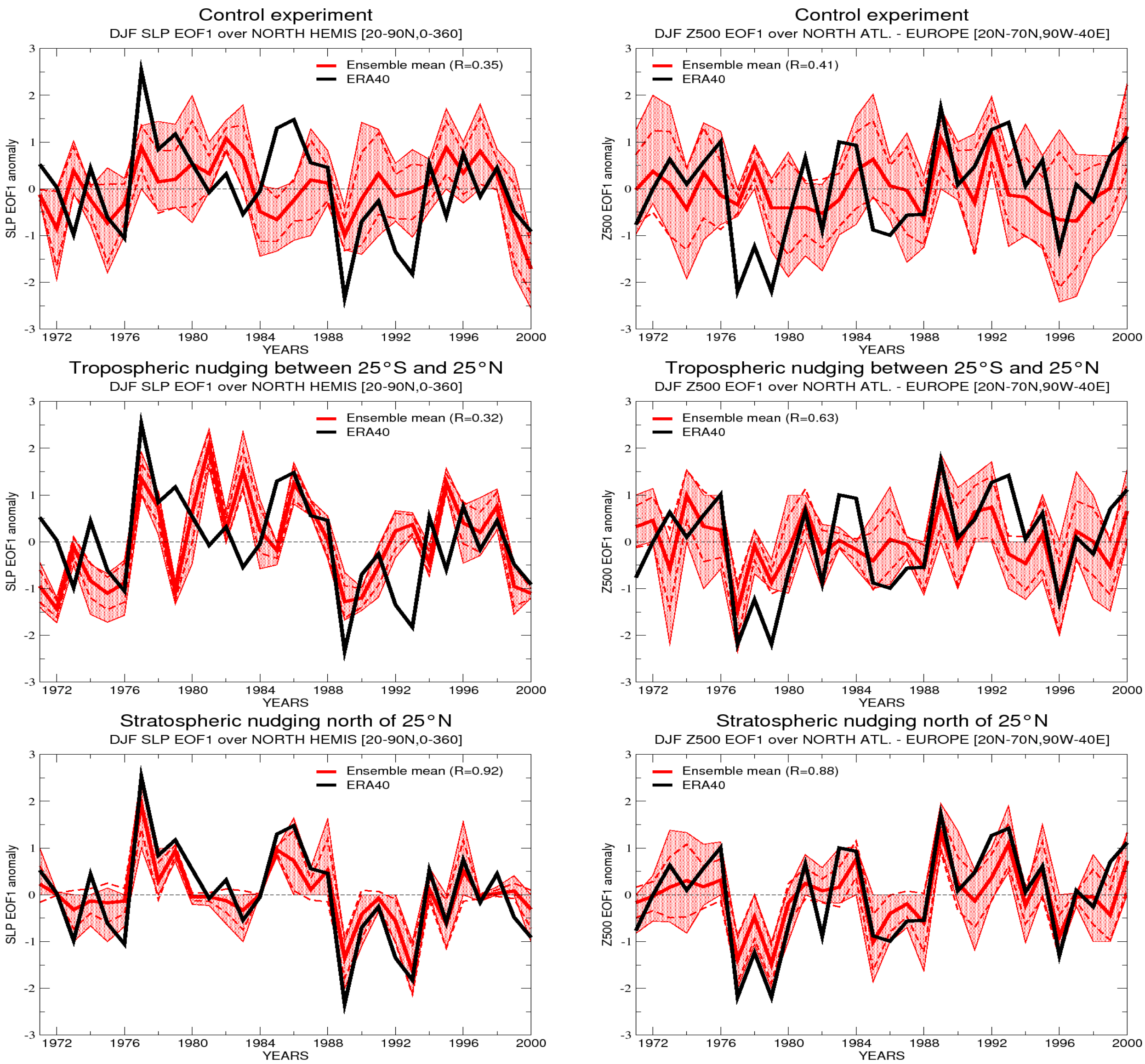

Figure 1: 1971-2000 timeseries of DJF AO (left) and NAO (right) principal components: Control experiment (top), nudging of the tropical troposphere (middle) or of the extratropical stratosphere (bottom). For each experiment (in red), ensemble mean anomalies (thick line) are compared to ERA40 (in black) and spread is also shown (+/- 1 standard deviation in dashed lines and minimum and maximum anomalies in solid lines). R is the ensemble mean anomaly correlation coefficient with ERA40.

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